CHAMBERS'S

PAPERS FOR THE PEOPLE.

WATER SUPPLY OF TOWNS.

WATER, in consequence of its intimate connection with so many of the tastes, conveniences, and necessities of life, becomes a subject of universal and never-failing interest. Its position in the landscape as sea, lake, and running stream, affects the sense of beauty; to the eye of the naturalist engaged in classifying and describing the contents of the globe, it is a substance having numerous properties and relations; it is a grand example of the mechanical laws and gravitating power impressed upon all material things; and as an agent in the economy of the world, it enters largely into the operations of production and change. It is the highway of the world, the cheap defence of nations, the boundary of possessions, the element of existence to an immense living population. Lastly, it is an indispensable requisite and manifold convenience of the every-day life of human beings: alike to the uncivilised and civilised, to the roaming tribes of the wild, and the settled inhabitants of our crowded cities.

The uses of water in daily life lead to the adoption of means for providing it in proper quantity, quality, and readiness to every place of human habitation; and among the various arts that make up our civilisation, this has a leading position of importance. Of late years, great improvements have been introduced into the department of the public water supply, and efforts continue to be made towards still farther improvements. Our object in the present Paper is to touch upon the chief points of information connected with the sources and qualities of water, and the public arrangements for the supply of town populations—restricting ourselves solely to the condition and requirements of our own country.

SOURCES OF WATER SUPPLY.

The great masses of liquid constituting the seas and oceans of the globe, are unfit for many of the purposes of water, on account of the excess of soluble matter they contain, dissolved out of the solid crust of the earth, and concentrated by the evaporation of ages. Sea water, besides its principal ingredient, common salt, contains salts of lime and magnesia in considerable amount, and cannot be used for drinking, cooking, or washing. But the process of evaporation or distillation constantly going on over the whole liquid surface of our planet, yields to the atmosphere a pure supply—and this descending as rain, may be collected in situations where it is not permitted to acquire the disqualifying ingredients of the ocean liquor. Sometimes a water contracts impurities at one part of its course, and is freed of them at another part: the connection with the solid earth is not wholly a cause of deterioration. The chief sources of supply may be described as surface-collection, rivers, and springs:—

Surface Collection.

Water descending in rain may be ranked as a species of distilled water, and if collected on clean surfaces, it will be the purest which nature can supply. In its descent through the atmosphere, it brings with it a quantity of common air, together with any other gases that may be afloat, and also the fine particles of dust raised by the wind, and continually present in the lower stratum of the aërial ocean. A certain small amount of impurity is thus contracted before it reaches the ground; but what is of still more consequence, water in this condition has an intense attraction for the saline and other soluble matters which it finds on the surface. What are termed organic impurities, or the corrupting ingredients derived from vegetable and animal bodies, living or dead, are taken up in large quantities by rain water, so that a very short time suffices to taint the fresh-fallen shower. Hence the water caught on house-tops, although admirably adapted for washing, is not usually pleasant for drinking: part of the unfitness, however, arises from its wanting the proper degree of coolness. Rain water collected on shipboard is noted for its tendency to rapid putrefaction. Surface water, therefore, with its freedom from saline ingredients, has the disadvantage of possessing a strong affinity for organic impurities, these being diffused over every surface in the neighbourhood of living beings.

But surface water, considered as a source of supply, is not the same as the rain water gathered from house-tops. If we resort to a barren district of rock or sand, destitute of vegetation, and remote from the pollution of towns, we may obtain water such that, notwithstanding the solvent power of the fresh-fallen rain, hardly any organic impurity has entered into its composition. Accordingly, water in this condition may be a highly proper source of supply. It cannot be said of any surface beforehand that it is eligible as a collecting-ground; very careful examination of the water actually collected, especially in the hot months of summer and autumn, is required to determine this point. The grand advantage of this mode of supply is—the absence of salts in solution, rendering the water soft in respect of washing, and free from any peculiar taste of soda, magnesia, iron, or other mineral impregnation. The disadvantages are—first and principally, the presence of organic impurities; next, the necessity of impounding reservoirs so large as not only to secure that the excess of the wet months may avail for the deficiency of the dry months, but even that the excess of a wet year may be transferred for the supply of an unusually dry year; and lastly, the impossibility of obtaining water sufficiently cool for drinking in the warm season. Notwithstanding these general defects, it happens in various places that a surface supply is the best that can be had, and is, on the whole, satisfactory.

Rivers.

The water obtained from running streams is in part what has flowed immediately from the surface, and in part the water of springs, shallow or deep. In any case, a considerable amount of contact with the ground has been permitted, and in consequence saline matter is liable to be dissolved in a greater or less degree. The extent of the impregnation, as well as the kind of material dissolved, will depend on the rocks and strata of the river basin. Water flowing from granite rock, as the river Dee in Aberdeenshire, has a very small quantity of dissolved salts. Slate formations are also favourable to the purity of the water flowing over them. Sandstone is very inferior in this respect, while the limestone and chalk covering large districts of the country impart a nearly constant amount of lime-salt to all the running streams. The lime is not unfrequently accompanied by magnesia; and when this last substance is present in great quantity, it marks out a distinct and peculiar species of water.

River waters, besides the qualities they derive from their primitive sources, are apt to contain mud and matters in suspension, and are thus deficient in the clearness and transparency so essential to the satisfaction of the eye in a drinking water. The agitation which a running river undergoes prevents stagnation and such decay of organic matter, sometimes with an offensive smell, as occurs in canals; but it also deprives the water of some air and free carbonic acid, which renders it, according to the opinion of many, less fresh to the taste. Moreover, the water partakes of the extremes of summer and winter temperature, and in the hot months can hardly be free of organic impurities and insects. But, on the other hand, the supply from one of our large rivers is boundless and unfailing; and it conveys the surface drainage and spring effusions of a large tract of country without incurring any trouble or expense as to the original sources. With far more of mineral impurity than surface water, river water will usually present less of vegetable and animal impurity, in consequence of the tendency of the mineral impurity to increase, while the organic impurities diminish, by time and exposure.

Springs.

When water falling on the surface of the ground sinks into the soil, descending downward by slow percolation till it encounters an impervious bottom, and rises up at some convenient opening by the force of hydrostatic pressure, the outgush is called a spring. Beds of sand and gravel, as well as the surface-coating of soil, allow a free passage to water; but its course is as completely checked by a bed of clay as by the solid rock. Hence the course of the percolation follows the direction of the porous beds. It may happen that water, in pursuing a lateral direction in the pervious strata, passes beneath as well as above an impervious layer; and between the two it will be hemmed in with the whole force of the downward pressure at the spot where it enters the soil. If there be no outlet, the pervious stratum thus enclosed will be saturated and choked, and the water must either find some other course, or lie stagnant on the surface; but if an opening occurs anywhere in the upper enclosing bed, through it will the water rush up with a force determined by the difference of level between the mouth of the opening and the surface where the rain first enters. Springs are often formed artificially by boring in this way through a bed of clay or rock, in order to tap a deep porous layer charged with water, the result of steady percolation from some distant surface. Sometimes the passage of the liquid is by fissures and crevices in the rocks—at other times by compact beds of shingle, sand, or gravel. The gravitating force carries it downward to the lowest depths that it can reach, and again upward so as to find one level in every direction. Hence water falling on high grounds, and entering the soil, is sure to emerge somewhere on the low grounds, perhaps with a considerable pressure. If we could conceive a mountain formed of a porous top and impervious side, so as to retain the water while it sinks into the mass—and if this impervious layer were to cease at the foot, the water would pass down as in a siphon, and burst out with energy at the termination of the layer in question. But this upper stratum might be conceived to extend for miles along the plain in unbroken continuance, in which case the mountain water would have no opportunity of showing itself; till at last some interruption or cleft, or some excavation by the hand of man, occurs to relieve the pent-up waters; and out they flow with the high pressure still upon them, nobody being able to guess where they had their origin. The conditions necessary to the occurrence of springs are therefore:—1*st*, The rain falling on the higher grounds must find admission into the interior to some considerable depth; 2*d*, By the force of the pressure from above it must pass in lateral directions—in other words, it must find pervious beds or openings right and left; 3*d*, It must become hemmed in above by some stratum that does not give an easy passage, and therefore concentrates the pressure on the places where openings occur; and 4*th*, In the lower grounds where it has descended beneath an obstructing bed, there must be interruptions, fissures, or pervious strata, whereby it can rise to the surface again. Mountain districts, and a varied and irregular stratification of alternating pervious and impervious layers, are favourable to the concentration of water and its discharge in the form of springs; while, on the other hand, flat regions and uniform coverings of sand and gravel render springs impossible. In this last case there would be a uniform soakage of the soil, varied only by such shallow pools, lakes, and rivulets as the inequality of the surface could give rise to. A compact rocky formation, without fissures or other communication with the subterranean depths, would likewise be devoid of springs; the water prohibited from filtering its way into the interior would pass down at once over the surface to seek the lowest level that it could find.

The slow percolation through the interstices of a gravelly layer, or by the crevices of rocks, is the cause of the mineral impurities which distinguish the water of springs. At the same time, this slow action most effectually rids the water of any organic impurities contracted at the surface. Air, too, is largely taken in along with the saline matter of the rocks, and the temperature of the interior is imparted to the whole mass; whence it happens that springs of moderate depth represent the average temperature of a climate. Very deep springs are of a higher temperature. The qualities that recommend water to the eye and to the palate belong in a pre-eminent degree to spring water: it is clear, sparkling, and cool, and is totally free from the offensive taint so common in all other waters, as well as devoid of the animalculæ generated by organic impurity.

From this brief sketch of the principal sources of supply we now pass to a more minute description of the various qualities of waters.

QUALITY OF WATER.

Quality in water has reference to one or other of the following points:—1*st*, The presence or absence of mud or other solid matters in suspension; 2*d*, Salts and mineral matters in solution, which do not affect the clearness or transparency of the liquid. Some of these salts cause the property commonly known by the name of *hardness;* 3*d*, Organic matter, or the products of vegetable and animal life; 4*th*, The presence of atmospheric air and carbonic acid, and also of certain offensive gases, the result of the decomposition of organic matter; and 5*th*, The temperature.

Solid Impurities.

When running water comes upon a loose bottom, it carries the finer particles along with it, and the quicker its flow the larger the pieces that it can keep afloat. If the water comes into a position of perfect stillness, the matters thus floated gradually sink to the bottom again—the heaviest first, and the others in succession. Should any portion consist of fine impalpable dust, such as is raised by the wind, and floats in the stillest air, the subsidence is very slow indeed; days, or even weeks, may not bring about a perfect clearance. The particles gathered from beds of clay are the most difficult to separate from water by mere subsidence; either they are in a state of greater fineness than particles of lime, silica, or other minerals, or else the water has a more than ordinary adhesiveness to the material of clay. Whatever be the reason, the agitation of water in contact with a clay surface imparts a drab or rhubarb colour, arising from the diffusion of fine solid particles; and a river once contaminated in this way seems never to become clear again. The stagnation of streams in very flat districts, such as the fen countries of England, contributes to their defilement in this particular. A rapid current sweeps away all the loose particles lying in its bed, and leaves nothing at last but rock or pebbles too heavy to be moved; hence it is only by wearing off the hard surface remaining that quick-flowing streams make themselves muddy. Rivers draining cultivated land generally contain a portion of the loose soil, especially after heavy rains. The water most free from solid impurity is that derived from springs or which flows over barren rocks.

The earthy matters of soils and rocks are not the only solid impurities that may occur in water. In some circumstances iron and lead may be found in suspension. Vegetable and animal matter, not to speak of live insects, may likewise be present in solid specks. The drainage of a town is a compound of salts dissolved, and of solid matters suspended, in the current, both classes of substances being useful as manure.

The methods of clearing water from mud and matters in suspension are subsidence and filtration. The method of subsidence proceeds on the supposition that the solid earthy particles are heavier than water, and will gradually sink to the bottom when the mass is perfectly still. For the grosser kinds of mud this is quite true, but the fine, impalpable, drab-coloured clay is not displaced in this way. The other method, filtration, we shall describe in a subsequent section.

To separate clay powder from water, the practice has long been resorted to in India and China of putting in a piece of alum, which seems to act by the property it has of curdling some organic substances, and of causing others to adhere as dyes to such solid matters as may happen to be in the water. This is the oldest known device for purifying water by anything approaching to a chemical process.

Dissolved Impurities.

The impregnations of salts and mineral ingredients gathered up from the earth's surface are very numerous. The following statement by Professor Clark of Aberdeen, given in evidence before the Health of Towns Commission, contains an enumeration of the principal impurities of this class :—

Being asked, 'You have stated that the water usually contains saline impurities; of what do those consist?' He stated in reply—'The most material are earthy salts; that is, salts of lime and salts of magnesia. I call the earthy salts the most material, because it is the presence of earthy salts that gives rise to hardness. There is also usually present common salt, and sometimes bicarbonates of soda and potash; but none of these affects the hardness of water. The most important portion of the earthy salts may be reckoned the bicarbonate of lime. The whole salts present, whether earthy or not, may be distinguished into two parts—according as they are neutral to test paper, or alkaline to test paper—the neutral portion, and the unneutralised portion. The unneutralised portion consists entirely of bicarbonates, those of lime and magnesia, which are the earthy bicarbonates, and in some waters those of potash and soda, which are the alkaline bicarbonates. The neutral portion consists of the neutral salts of earths and alkalies—such as gypsum and common salt. Salts of iron occur also occasionally in waters that are in use. Such salts impart an inky taste to the water, and they give a yellowish tint to linen that is washed by the water containing them. They, too, produce hardness.'

Of the salts thus enumerated the foremost are salts of *lime*. The bicarbonate of lime is the chief example of what Professor Clark terms the *unneutralised* division; this bicarbonate is derived from chalk or limestone, and may be considered as chalk (carbonate of lime) with a double dose of carbonic acid, which second dose changes the chalk from an insoluble salt into a soluble one. The waters having bicarbonate of lime for their chief impurity are familiarly spoken of as the 'chalk waters.'

Of the *neutral* salts of lime, the chief instance is sulphate of lime or gypsum. The important distinction between the bicarbonate and the sulphate lies in the fact, that the first, the bicarbonate, may be in great part precipitated by boiling; whereas the second, the sulphate, cannot be so precipitated. The hardening quality of the one is therefore curable by a simple process, whereas the other is not affected by the same process. Of the two kinds of impurities, the chalk is much less objectionable than the gypsum. The river Thames and its tributaries, and the shallow springs of the London basin, are chalk waters, and all of them may lose upwards of two-thirds of their chalk and of their hardness by prolonged boiling.

The salts of lime are chiefly injurious on account of their giving to water the well-known quality termed hardness, of which we shall afterwards speak. No bad effect on the human system can with certainty be attributed to lime occurring by itself in any water; but the notion sometimes entertained, that this salt is either indispensable or salutary in the water taken into the animal body, is without the smallest foundation.

The other class of salts coming under the head of earthy salts are salts of *magnesia.* Magnesia is apt to be present in small quantity along with chalk and other salts of lime; when it exists in any large proportion it determines a very distinct species of water, of which examples have been found in Leicester and Birmingham. Magnesia does not produce hardness with the same regularity and precision as lime does; in the company of lime it sometimes does not occasion the consumption of more soap, but only causes the soap-suds to curdle. This curdling of the soap renders such waters particularly unfit for the washing of clothes.

Although there is the same uncertainty as to the positive effects of magnesian waters on the animal system that there is in respect to lime waters, yet as salts of magnesia in large doses are known to act as powerful medicines, it is barely possible that it may have some medicinal influence, but probably of a different kind, in the small doses occurring in an ordinary magnesian water. A recent observation by Graves, a foreign physician, that magnesia is the characteristic ingredient of waters in the districts where the diseases called *crétenisme* and *goître* (wens) abound, is worthy of attention. The surmise has sometimes been made, that certain waters supplied to towns, containing a large amount of saline matter in solution, have been instrumental in fostering diseases among the population, but the fact has not been ascertained with rigorous certainty, still less has the injurious ingredients been discriminated from others not injurious. Nevertheless enough is known to render all waters abounding in lime, magnesia, or other salts, highly undesirable in the supply of towns.

Of salts of *soda* and *potash* the principal is common salt, or the muriate of soda. Sulphate of soda—Glauber's salt—occurs along with the muriate in the salt springs of watering-places as well as in the sea waters. None of all these salts have any effect on the hardness. In the case of sea water, which is very hard, the effect is not due to common salt, but to the lime and magnesian salts dissolved in it; were it not for these, sea water would be perfectly suitable for washing, although not for drinking. The high proportion of soda salts contained in some springs unfits them for common use. The salts of the alkalies, soda and potash, as distinguished from the salts of the earths, lime and magnesia, are undoubtedly very active as medicinal agents, and are therefore objectionable ingredients of water when present in any great amount. The Artesian-well water of London contains a large amount of alkaline salts. As an example—a well 400 feet deep, sunk at the Camden station of the Great Western Railway, is found to contain about forty-two grains per gallon of soda-salts, muriate, carbonate, and sulphate, with hardly a trace of any earthy salt; and the general character of these wells is, to have a small portion of earthy matter, such as lime or magnesia, and a very large portion of soda or other alkaline salts. The water is extremely soft for washing purposes, and well adapted for cookery; but it is doubtful if so great an amount of alkali habitually imbibed be not injurious to the bodily system.

Salts of *iron* in considerable quantity make what is technically named *chalybeate* waters, and belong to the medicinal class. When the iron exists in the spring as carbonate, which is the most usual case, on exposure to the air it is changed into the peroxide, and falls down in the form of an ochrey precipitate.

Hardness of Water.

The quality of hardness in water is commonly recognised by the difficulty experienced in washing, and by the amount of soap necessary to form a lather. This quality is injurious also in the preparation of food; but its action is most universally felt in washing operations. It occasions an enormous waste of soap, an extra labour in washing, and a corresponding tear and wear of clothes.

The most usual hardening ingredients are the salts of lime. Every lime-salt whatsoever hardens water and destroys soap in proportion to the lime present. Salts of magnesia are hardening salts, but not in a regular proportion to the quantity, there being some irregularities in their action.

Professor Clark has devised a scale of hardness which is now universally employed in the chemical description of waters. The hardening effect that would be produced by one grain of chalk dissolved in a gallon of water is one degree of hardness; in like manner four grains per gallon would produce four degrees of hardness; ten grains ten degrees; and so on. The degrees are expressed in numbers—thus 1°, 4°, 10°, 15°, are one, four, ten, fifteen degrees respectively. When any other salt of lime is the hardening ingredient, the measure is still by grains of chalk; if a certain amount of gypsum be dissolved in water, the effect is not expressed in grains of gypsum, but in the grains of chalk requisite to produce the same hardening effect. An equal quantity of calcium, the metallic base of all the lime-salts, will always produce the same degree of hardness whatever acid it be combined with—that is, whether it be carbonate, sulphate, muriate, or any other combination of lime. Hence it is very easy to calculate the number of grains of any salt which will produce a given degree of hardness; but it is always to be understood that when hardness is caused by any other salt than the carbonate—by gypsum, for instance—the number of degrees does not express the number of grains of that salt per gallon; and on the other hand, if a water were said to possess ten grains per gallon of gypsum, that would not constitute 10° of hardness; the computation would show only 7⅓°; indeed if 7⅓ grains of chalk were converted into gypsum, they would produce 10 grains. But in an analysis setting forth a given number of grains of carbonate of lime, that number would strictly express the degrees on Clark's scale.

The scale of hardness increases with the consumption of soap requisite to form a lather. Professor Clark has made use of this fact in his process of testing for hardness—a process of extreme delicacy. It consists in the employment of a solution of soap of measured strength; and according to the quantity of solution requisite to form a lather of a certain duration is the hardness of the water. By this test the value of a water for washing purposes, and for all other purposes where hardening matter is an objection, can be determined with great ease, and with a precision scarcely equalled by any process in chemistry. The employment of the definite scale of hardness, and of the soap test for measuring its amount, has tended more than any other circumstance to facilitate the determination of proper waters for the supply of towns.

Next to washing, the deleterious consequences of hardness are felt in various culinary operations, and especially in the infusion of tea. It is a fact of universal experience that hard water is unfit for tea; but as yet the only approach to an accurate determination of the effects of different degrees of hardness is seen in the following question contained in Professor Clark's Evidence to the General Board of Health :—

'It is generally admitted that hard water is unfit for the purposes of washing and cooking? With regard to cooking, perhaps the most important material is tea. I have been very desirous of making experiments on waters of known degrees of hardness upon a given average of tea, with the assistance of some gentleman experienced in the tasting of teas for commercial purposes. My health has heretofore prevented me from making any more than merely preliminary experiments. From these it appeared that hard water was very unfit for the purpose of making tea. In making use of a series of waters at 4°, 8°, 12°, 16° of hardness, the strength of the infusion, as manifested by the depth of colour produced, was evidently in a series such that each infusion could be sensibly distinguished from the one next to it, above or below, the hardest water giving the least depth of colour, and the softest water the greatest. At 4° of hardness the infusion was transparent, with no sensible muddiness; at 6° the transparency of the infusion began to be injured; at 12° there was a distinct muddiness; at 16° this muddiness had become very decided; and above 16° it was disgusting. No such muddiness appeared with any of the waters after pouring off the first infusion and making a second. With regard, again, to depth of colour, it is very worthy of remark, that whereas the greatest depth was observed in the first infusion in the softest water, and the least depth in the hardest, now, in the second infusion the same thing was observed again, with this difference, that in the harder waters the depth of colour was proportionally still less; not only absolutely less, as might be expected, but relatively less. In making these experiments, about half an ounce of tea was made use of with a pint of boiling water; so that you will understand the result if you suppose in each of two similar teapots half an ounce of tea be put, and over each a pint of boiling water, but in the one case at 4° of hardness, and in the other case at 16°, the infusion at 4° will turn out much stronger than the infusion at 16°: the infusion at 4° will be transparent; the infusion at 16° will be offensively muddy. But supposing you pour off the first infusion, and make a second infusion, then the second infusion at 4° will be a little weaker in colour than the first infusion at 4°; while the second infusion at 16° will be of a still proportionally weaker colour than the first infusion at 16°. In short, hard water is bad for a first infusion, still worse for a second. The only way of making an infusion of tea with waters at 8°, 12°, or 16°, equally strong with an infusion by water at 4°, is to increase in each case materially the quantity of tea infused. Sub-carbonate of soda in crystals may be made use of in very small quantities, in order to soften the water, and make it fitter for the purpose of infusing tea; it produces this effect by decomposing the earthy salts present; but if made use of in any proportion beyond above what will exactly decompose the earthy salts present, the excess may indeed deepen the colour of the infusion—by dissolving some coloured vegetable extract, such as pure water would not dissolve—but it will infallibly injure the fine flavour of the tea to all persons not accustomed to the taste of soda in their tea.'

According to M. Soyer—who was requested by the General Board of Health to try the effects of hard and soft water in cooking, and was provided with solutions of known hardness for that purpose—the operation of hard water is prejudicial both to meat and vegetables.

From the foregoing experiments on tea, it will be seen that when water approaches to 8° of hardness, it begins to be decidedly unfavourable to the infusion. It may be stated generally, that for the purposes of washing and cooking a water of less than 6° is soft, but above this point the hardness becomes objectionable. At 8° the water is moderately hard, at 12° it is very hard, at 16° the hardness is excessive, and much above this it is intolerable. It must always be borne in mind, however, that a water reducible to 6° by ordinary boiling is not an extremely objectionable water, even although in its unboiled state it may have as much as 12° or 16° of hardness. But a water such that boiling will not reduce it to 6° may be reckoned as altogether unsuitable for a town supply.

To make these observations more intelligible, we may mention a few instances of known waters with their place in the scale. The water of the Dee at Aberdeen, which is used for the supply of the town, is 1¼° of hardness; this is about the greatest softness ever found in a natural water, and is attributable to the granitic character of the river basin. The river Clyde, supplying Glasgow, is 4½°, and may also be reckoned a soft water. The Thames at London, as well as the New River, is about 13°, while many of the tributaries of the Thames rise as high as 16°; but being all chalk waters, they may be materially softened by boiling. Springs from the chalk commonly range from 16° to 18°; but particular springs are to be met with in some parts of the world four or five times as hard, from the presence of bicarbonate of lime. In many parts of the continent hard waters abound; but the testing of waters has not been so much attended to there as in this country. If, however, the hardness of continental waters were as great generally as it is known to be in some districts, a reason would be afforded for the comparatively limited use of tea in continental countries.

The operations of the General Board of Health have led to an extensive examination of the waters of England and Wales, which has yielded the following important result, stated in the Board's Report on the Metropolitan Water Supply:—

'We had 424 different specimens of water from different parts of the country tested, and we find that, in respect to hardness, the following are the results:—

'1. Wells and springs (264 specimens), average hardness, 25°·86.
'2. Rivers and brooks (111 specimens), average hardness, 13°·05.
'3. Land and surface-drainage (49 specimens), average hardness, 4°·94.'

It thus appears that in England the hardness of springs in general is excessive; that a very large number of rivers have an injurious and exceptionable amount of hardness; and that surface waters may be collected in a state that is to be considered soft.

Alkalinity of Waters.

All the salts that exist in a water in the form of bicarbonates have an alkaline action when tested by litmus paper. Not the bicarbonates of the alkaline salts merely—those, namely, of soda and potash—but also the bicarbonates of the earths, lime and magnesia, have an alkaline character. The bicarbonate of lime, therefore, which is a cause of hardness, is also a cause of alkalinity. Professor Clark has made an important application of this fact, by introducing an alkaline test, to ascertain whether a lime salt present in a water be a sulphate or a carbonate of lime. The test for hardness, taken by itself, does not show what substance causes the hardening effect, and more especially it fails to point out whether the hardening salt can be precipitated by boiling. But should it be found that a water, whose saline contents are chiefly salts of lime, has an alkalinity as great as its hardness, it is evidently a chalk water, and not a gypsum water. Ten degrees of hardness due to chalk would cause 10° of alkalinity (one degree of alkalinity being what is caused by one grain of chalk dissolved in a gallon of water): 10° of hardness due to gypsum would show no alkalinity. The great use of the alkaline test is to distinguish between the carbonate and the sulphate of lime, or between the curable and the incurable hardness.

In the complete process of testing water introduced by Professor Clark, and employed on all waters tested for the General Board of Health, the hardness and alkalinity are determined in the water first unboiled, and next after boiling for two hours without loss by steam. The results of such an examination leave scarcely any practical point to be desired with reference to the mineral impurities of a water. Not merely is the hardness known, but the cause of it is ascertained, and also the effect of boiling in diminishing its amount. Some chemists are accustomed to ascertain also the total saline matter present by evaporation.

Presence of Lead in Water.

Injurious effects have frequently arisen from the contamination of water with lead, derived from leaden pipes and cisterns. Some kinds of water are known to act powerfully on a leaden surface, and the effect is ascribed by chemists to the carbonic acid contained in the water. Distilled water has a very great power of absorbing carbonic acid, and is remarkable for wearing down leaden surfaces. Any excess of carbonic acid is sure to bring about a corroding action both on iron and on lead.

Water freely exposed to the air, and containing organic matter, acquires free carbonic acid. Should this water flow over a bed of lime, the carbonic acid will cause carbonate of lime to be dissolved, thereby forming the bicarbonate of lime, or the salt peculiar to chalk waters. In this way the carbonic acid will expend itself, and such a water will not be liable to act on lead. But when no bicarbonate is formed, the acid remains in its free state, and is a source of evil.

A remarkably soft water, obtained from Bagshot Heath, near Windsor, was found to have poisoned some of the Queen's hounds, and brought on painters' colic on one of the huntsmen. On this water Professor Clark has made the following interesting statement to the General Board of Health:—'Through the kindness of Sir James Clark, I obtained a specimen of this water, and in a few days came to the unexpected result that filtration would separate the lead. Thus a very simple practical means for separating lead, wherever it contaminates water, was discovered. This was in the summer of 1843. But the process first came into practical use in spring 1844. At a marine villa of Lord Aberdeen's, some of the servants suffered in health from lead in water derived from pipes. Sand filters were put up under my direction at this villa, and subsequently at Haddo House. On making inquiry recently at his lordship's agent in Aberdeen, I learn that the filters have been in use ever since, and that the waters have been tested from time to time, without any lead having been discovered in them.'

The above discovery as to the purification of water from lead depends on the fact, that the lead, although not always perceptible to the eye, is not usually dissolved in the water, but floats as a solid powder, and can therefore be arrested by a filter. In the cases where the lead happens to be dissolved, which are not so frequent, filtration would not remove it.

The accident with the Bagshot water has led to the supposition being taken up that hard waters do not act upon lead, and that the hardness being a minor evil, it should be tolerated, rather than run the risk of being poisoned with soft water. But it is found that soft waters do not act upon lead in proportion to their softness, and that the presence of a large amount of saline matter does not uniformly give exemption from lead. The Aberdeen water, of little more than one degree of hardness, and containing less than 3½ grains of solid matter, is found to have very little action on lead pipes; while waters of much greater mineral impurity have a very decided action. The fact is, that the Aberdeen water, being derived from a rapid river, the free carbonic acid is expelled by the agitation that it undergoes; for agitation is found by chemists to be an efficacious means of driving off this gas from a liquid solution; and, as a general rule, river waters contain no excess of carbonic acid. Moreover, there may be salts present with free carbonic acid in addition, in which case the salts will not prevent the corrosion of the lead.

In drawing water from lead pipes after it has stood for some time undisturbed, it is advisable to let the first portion of it run off before any is taken for use. With this precaution, little danger can arise from the use of lead in *pipes;* but either leaden *cisterns* should be wholly avoided, or means taken to ascertain whether they contaminate the water; and if so, a remedy should be applied. The substitution of slate for lead in the lining of cisterns has been recommended by the best authorities.

Organic Impurities.

The contamination of water by vegetable and animal substances in a state of putrid decomposition, and by the minute forms of life bred among such impurities, takes place in various ways. The most obvious and abundant source of this class of ingredients is the sewage and refuse of towns, and next in order may be ranked the contact with soils rich in organic matter. Among organic impurities may be classed offensive gases, such as carburetted, sulphuretted, and phosphuretted hydrogen; vegetable fibres in a state of rottenness; putrefying products of the vegetable or animal kingdoms; starch, muscular fibre, &c.; urea and ammoniacal products; Vegetable Forms—algæ, confervæ, fungi, &c.; Animalcules—infusoria, entomostraceæ, annelidæ or worms, &c.

There may not be any very clear evidence as to the precise effects of these impurities on the animal system, but the single fact of their rendering the water repulsive to the taste, and nauseous to the stomach, is sufficient to condemn their use. There is, indeed, a very great probability that waters highly tainted with putrid matters and loathsome insects are a frequent cause of diarrhœa, especially in the hot months: the aggravation of the epidemic of last year by this means was shown in many instances. What is disagreeable to the senses must be presumed to be unwholesome in addition, until the contrary is proved; but the wholesomeness of water abounding in vegetation, insects, and decaying products, has never yet been affirmed by any competent judge.

Water falling on a growing soil, and running off the surface to lie in stagnant ponds, is in very favourable circumstances for being tainted with vegetation and animal life. Water-plants will spring up and feed numerous tribes of animalcules, and each pool will be a constant scene of vitality. In such a state the water is usually unfit for drinking; the palate instantly discerns a disagreeable taint, and no one will use it who can do better.

The surface water of a district overgrown with peat-moss has usually a peaty flavour, as well as a dark and dirty colour. The infusion of peat does not breed animalcules, it being the opposite of a putrid substance—that is, it rather arrests than promotes putrefactive decay—but it is an objectionable ingredient nevertheless. Slow filtration has been found to remove the colour of the infusion; but if the filtered water be exposed to boiling or evaporation, the colour returns, showing that the peaty matter has not been altogether removed. It is perhaps doubtful whether any specific unwholesomeness can be justly attributed to peat water; but it is unpalatable, and the use of it is shunned by the inhabitants of peaty districts, especially in the hot months of the year, and even by the cattle. The presence of peat in the lands used as collecting-grounds for surface water—and it is generally such worthless tracts which are so employed—is a disadvantage attending that mode of supply.

The most frequently-occurring source of impurity, as already stated, is the contamination of wells and running streams by sewage. A number of important observations have been made by Dr Angus Smith of Manchester, on the waters supplied to London, at the request of the Metropolitan Sanitary Commission and the General Board of Health; and by these observations he has been able to trace the process of purification from such matters going on in nature—namely, the formation of the class of salts called nitrates, of which class saltpetre is a member. Matter that is at first in the state of impure decay, offensive to the senses, and productive of loathsome insects, becomes in course of time a stable and harmless product. Dr Smith was enabled to measure the quantity of organic impurity in the river Thames at different points by the amount of dissolved nitrate obtained from each point. He commenced his examination at the sources of the river, and continued it all the way to London Bridge, taking up specimens at successive stations. He found by this means that as the river became mixed with the sewage of the towns on its banks, the organic impurity increased accordingly, and with it the amount of nitrates, and other indications of such impurities.

Dr Smith found in some of the London wells an extraordinary amount of nitrates. The old well at Clerkenwell was found on examination to contain 148 grains of solid matter to the gallon, of which a part was nitrate of lime. If the filtration through the earth has been sufficiently prolonged to convert all the animal matter into nitrates, and to destroy other organic matter, the water will be pure, as far as the organic taint and the presence of animalcules are concerned, and will in fact be neither disagreeable nor unwholesome. Hence it may happen that wells deriving part of their supply even from water that has been in contact with cesspools and churchyards, may be fit for use—the organic matter having gone through its final transformation, and settled down into a mere mineral impurity. The process of natural filtration through beds of earthy matter is particularly favourable to the destruction of vegetable and animal remains. But in the rivers, the nitrates which represent the last stage of decaying matter are accompanied with the matter itself in its offensive condition.

Dr Smith proved by direct experiment that decomposing organic matter passed through a filtering bed was changed into nitric acid. 'A jar, open at both ends, such as is used with an air-pump, was filled with sand and some putrid yeast, which contained no nitric acid, was mixed with pure water, and poured on the sand, and allowed to filter through. The production of nitric acid was abundant.' The process that takes place in an open river, as above described in the Thames, goes on much more rapidly and effectually in a natural or artificial filter-bed; and hence the fact of the purification of wells in bad neighbourhoods.

We are thus made acquainted with one of the ways employed in nature for the purification of water from organic taints of the worst description. If sufficient time be allowed for the work, a perfect transformation of the offensive remains of living bodies into inoffensive mineral products will always take place; and slow filtration will tend to hasten the process. In the river Thames, near London, the contamination goes on at a rate far beyond the power of natural purification in the open stream, and the water continually abounds with matter in every stage of decay. But in respect to other sources of water supply, a knowledge of this purifying process is important in allaying apprehensions as to the impurity of wells and springs suspected of too close proximity to drainage or other cause of pollution. If a tolerably thick bed intervene, the chances are, that a complete purification will be effected during the percolation; and at all events the water ought not to be pronounced bad on mere suspicion, nor until some of the decisive traces of organic impurity are apparent. On the other hand, mere surface waters, whether stagnant pools or running streams, are always liable to contain the untransformed and offensive kinds of animal and vegetable contamination.

Living Products of Organic Impurity.

We have already made repeated allusions to the occurrence of living vegetation and animals in water, of which some forms are visible to the naked eye, while innumerable others are disclosed by the microscope. These products in the London waters have been carefully studied by Dr Arthur Hassall, who has given valuable information respecting them, bearing on the practical arrangements for maintaining the purity of a town supply.

Dr Hassall states that the deeper wells, and spring water in general, contain little or no living organic matter. Consequently it is quite possible to obtain a liquid perfectly free from animalcules and vegetation; and it is not true that every drop of water teems with life. The presence of living creatures, vegetable or animal, discernible either by the naked eye or by the microscope, is a proof of organic taint in the water, and is one of the tests of this kind of impurity.

With respect to rain water, Dr Hassall states, in his evidence before the General Board of Health—'I have made several examinations of rain water immediately after its descent to the earth, obtained in both town and country, and can confidently assert that it does not, in general, contain any form of living vegetable or animal matter. In procuring rain water for microscopic examination, it is necessary, however, that certain precautions should be adopted in its collection: thus the vessel into which it is to be received should be placed far away from houses or other buildings, and also raised some two feet above the surface of the earth; or otherwise, in some cases, the drops of rain will bring down from the roofs and sides of houses sporules and filaments of *confervæ*, the ova of *infusoria*, &c. the former of which are frequently very abundant on damp walls, sheds, palings, trees, &c.'

Thus although rain water has a strong tendency to take up organic impurities, and become tainted, it is proved that it is not in any sensible degree contaminated when it first reaches the ground: at the moment of its fall it is the purest water that nature presents, being surpassed only by distilled water.

The conditions necessary for the development of vegetation and animalcules, over and above the presence of matter for them to feed on, are *air*, *light*, and *stillness*.

With regard to the probable effects on health of living creatures contained in water, we have already remarked that precise information is wanting; but Dr Hassall's observations on this head are worthy of attention:—'All living matter contained in water used for drink, since it is in no way necessary to it, and is not present in the purest waters, is to be regarded as so much contamination and impurity—is therefore more or less injurious, and is consequently to be avoided. There is yet another view to be taken of the presence of these creatures in water—namely, that where not injurious themselves, they are yet to be regarded as tests of the impurity of the water in which they are found.'

Tests of Organic Matter.

With regard to the modes of detecting the presence and measuring the amount of organic matter in waters, it is to be observed that none of them reach the accuracy of the tests for hardness, alkalinity, and mineral impurities in general. Hence the comparison of the merits of different specimens cannot be made with the same rigour as in the case of the other class of impurities. But at the same time there is no great difficulty in ascertaining that such matter is actually present, and there are means of approximating to the comparative amount.

1. The first method is that followed so successfully by Dr Hassall—namely, microscopic observation. The occurrence of the vegetable species and animalcules above-described is an infallible proof of the presence of organic impurity in its worst stages—that is, in the act of putrid decomposition, or in the course towards this consummation. These plants and animals feed upon the remains of other plants and animals, and cannot subsist upon mineral matter alone. A water is not perfectly pure if a single living being can live and procreate in it, and in proportion to the abundance of life is the amount of the impurity. The stagnant pond overgrown with gross slimy vegetation, and swarming with insect life and with innumerable microscopic animalcules, gives the highest possible evidence of its pollution. Moreover, in addition to the mere number of creatures that can be maintained on the foreign matters present in water, Dr Hassall has pointed out the fact, that particular species of creatures belong only to certain degrees and circumstances of pollution, so that the occurrence of a single specimen of such species stamps the character of a water at once. One species of the *paramecium* he designates as the Thames *paramecium*, because he found it in all waters derived from the Thames in the immediate neighbourhood of London.

From what has already been said, it will be apparent that in using the microscopic test regard must be had to the season, temperature, and other circumstances favouring the growth of living beings. If waters are to be compared with one another on the point of organic pollution, they must be examined under nearly the same conditions. The months of July, August, and September present the animalcular activity in greatest force, and during those months the examination of water by the microscope should be made. A water may show no living beings in the winter, and yet be far from pure; while, on the other hand, some streams, like the Thames, contain life all the year round, and differ in different seasons only in the number of species and of individuals.

The microscope will show the pollution of water from sewers by bringing into view solid particles that may be identified as belonging to the effete remains flowing away in the drainage of towns. Such matters were abundantly detected by Dr Hassall in his examination of the London waters.

There is a certain stage of pollution attained in the sewer water of the metropolis which is fatal to animal life, and consequently where animalcules cannot be detected. The poisonous gases (sulphuretted hydrogen, &c.) which make part of the contamination complained of in polluted water, are in this case too strong and too highly-concentrated for any species of living beings to exist in the midst of them. Dilution must take place before life can begin to appear.

2. The most usual chemical method of testing for organic impurity is to evaporate the water to dryness, and then to expose the solid residue to a red heat, so as to consume and dissipate everything but the earthy or saline portions. If the solid matter were weighed before being heated, and again weighed after the dissipation of the volatile ingredients, the difference would show what amount had been driven off; and this difference is set down as organic matter, while what remains is taken as the total earthy matter present. For example, if by evaporating a known fraction of a gallon of water, it were found that the total solid matter per gallon amounted to 12 grains, and that 9 grains remained after driving off the volatile portion, 3 grains would be reckoned as organic matter, and the remaining 9 grains earthy matter, contributing to the hardness, alkalinity, or other mineral quality of the water. When the amount of organic matter obtained in this way rises as high as 4 grains per gallon, it begins to be considered as excessive; while as much as 8 or 10 grains would form a most offensive degree of impurity.

The objections to estimating the organic matter by the loss on heating to redness are—1. That carbonate of magnesia, and even, when in contact with organic matter, carbonate of lime, may lose carbonic acid; 2. Chloride of magnesium, and possibly chloride of calcium, may give off some muriatic acid; 3. Nitrates, more especially in contact with organic matter, will lose oxygen (which, though the opposite to organic matter, will be reckoned as organic matter), and lose perhaps also their acid; 4. That some salts, particularly gypsum, will give off a last portion of water, very difficult to be separated at a lower than a red heat; 5. That some of the salts, particularly common salt, are apt to be volatilised at a red heat; 6. And finally, that the loss from these, and perhaps other causes, is apt to be proportional to the saline matter operated upon; so that the amount of error in heating to redness twenty-five grains of saline matter has a chance to be five times more than upon five grains; and consequently, the error on the estimate of the organic matter from the result thus obtained has a chance of being also five times greater.

3. The following method of ascertaining the presence of organic impurity has been practised by Mr Homersham the engineer:—Fill a stoppered bottle nearly full of the water, and put it aside in some dark place where it will experience a temperature of about 70° of Fahrenheit. After allowing it to stand a few weeks, draw the stopper, and apply the nose to the mouth of the bottle; if the water smells in any perceptible degree, it may be pronounced a tainted water.

4. Forchhammer has introduced a method of testing organic impurity by means of the decoloration of oxymanganate of potash. When this process has been so matured as to express degrees of a scale of impurity, it is believed capable of becoming a very effective test.

QUALITIES OF WATER FOR DRINKING.

On this subject we can do nothing better than present the following carefully-considered statement, occurring in Professor Clark's evidence before the Health of Towns Commission:—

'In the first place, the particular kind of water that is agreeable is dependent very much on the habits of the drinker. If you are accustomed, exclusively, for a certain time to a hard water, you acquire a liking for hard water; if to a soft, you acquire a liking for soft, just as habit varies the taste for other beverages. Putting the effect of habit out of the question, one circumstance, which I think is most material for water to be agreeable, is the temperature, especially in warm weather, when good water to drink is most prized. It has been supposed that water, such as is used in this town (London), being exposed in a room for some time, loses a portion of its carbonic acid. Everybody knows that water which has been in a sitting-room is not so agreeable as when first drawn; but I am quite satisfied that whatever be the cause of its becoming less agreeable, it is not in general the loss of the carbonic acid; for I am quite certain that there is not in any of the waters about London an excess of carbonic acid over and above what is necessary to form the bicarbonates present. I think the main point affecting the agreeableness of a water, as far as I have seen in examining water accounted agreeable in this town, is the temperature. In summer-time you have the spring waters, when fresh drawn, cool. You can have other waters rendered more agreeable than they are in summer-time, if you take the pains of cooling them to the same degree as the spring water. You must not have the water too cool either, otherwise it is unpleasant as well as unsafe to drink; but an average temperature of the climate, which is about 50° Fahrenheit, is a very agreeable temperature for water. So far as the presence of carbonic acid will add to the agreeableness of water—and it does so to many tastes—that quality can be imparted to any water by the simple expedient of adding a very small quantity of soda water. No doubt there are circumstances that make water offensive, particularly the presence of vegetable matter in a state of change, whether that matter be undergoing putrefaction or a vegetating process of any kind. In any such case I reckon the water polluted, and the taste is entirely tainted and offensive, especially to persons not accustomed to drink such water. But if water be free from taint, be of a sufficiently low temperature, and be not absolutely deprived of wholesome gaseous matter, I think it has most of the qualities proper to render it agreeable, allowing for the variations in taste that are acquired. If all these conditions contributing to the agreeableness of a water exist, then I think that such persons as have been accustomed to drink various kinds of water will be found to prefer a water containing little saline matter to another containing much; if a contrary impression has been usually entertained, it is owing to some of the other circumstances affecting agreeableness having been overlooked. At the present time (the month of June), in order to obtain good drinking water for London, I would recommend the use of water that has been boiled, cooled, treated with carbonic acid by the addition of a little soda water, and then iced to a temperature rather under 50° Fahrenheit; but all this pains to obtain good water cannot be taken by the poor, or even by the generality of families in the middle classes. I think that if the means were taken by the existing water companies, water only requiring to be a little cooled in the heat of summer to be fit for drinking by all classes might be supplied—and should.'

It is not generally suspected that the universal preference of spring water for drinking depends to a great degree on the accidental suitableness of its temperature for this purpose—a quality which of all others is the most easily affected and the most readily controlled. Surface waters and rivers have a repulsive coldness in winter, and a disagreeable, unstimulating warmth in summer; and at both extremes they would require to be artificially treated before being employed as a beverage. The icing of water down to the freezing-point in summer is not advisable; the use of a thermometer to ascertain when it has reached 48° would be much more to the purpose. Water should never be drunk below 45°.

Spring water is notable for containing a large quantity of atmospheric air, and occasionally of carbonic acid, which seems to contribute materially to its agreeableness as a drink. Exposure and agitation cause the loss of a large quantity of this dissolved air, and by so much tend to render the water vapid. Effervescing drinks owe their stimulating effect to an overdose of carbonic acid evolved in them by a chemical action. There is an easy means of giving a slight charge of carbonic acid to any water containing dissolved carbonates (probably one of the most prevalent ingredients of water), by dropping in a few drops of dilute muriatic acid; acid of the specific gravity of 1·10 may be recommended for this purpose. If the water be first boiled, in order effectually to destroy all organic taint, and if, after cooling down, it be slightly acidulated in this manner, the carbonic acid evolved will very sensibly enliven it and enhance its quality as a drink. In such water as the Artesian-well water of London, containing a large amount of carbonate of soda, this application would be found very effective. There is a form of vessel used by chemists for the express purpose of letting a liquor run out drop by drop; and with this the acid may easily be dropped into the water vessel.*

CHOICE OF A TOWN SUPPLY.

Too great pains cannot be taken in the first choice of water for a town supply. The whole district should be carefully searched, and the qualities and amount of every available source accurately tested. With the means now at command for examining waters, it is possible to fix upon the best within reach; so that, in fact, the most distant posterity may not be able to improve upon the supply. The expense incurred in the first determination of the best source should be held as nothing in comparison with the importance of settling the point once and for ever.

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* Some care is necessary in obtaining muriatic acid for such a purpose, and still more in the extensive use now made of it in the baking of unleavened bread, to make sure that it is perfectly free from arsenic. The effectual mode of testing for arsenic is to pass sulphuretted hydrogen gas through the acid, *having first heated it to the temperature of* 200°. If the liquor remain perfectly transparent, its purity may be relied on. Arsenic would at once produce a yellow precipitate.

The survey of a district for the choice of a water should be made both by an engineer and chemist; and each of the two should have special knowledge and experience on the question in point. The examination ought to be conducted under a variety of circumstances—after rain, and after drought, and especially during the warm months of July, August, or September, when every kind of surface water suffers most deterioration. All the accurate tests for mineral matter should be applied; the hardness and alkalinity determined, and the effect of boiling ascertained. If a soft water cannot be procured, it is best to choose the water that is softest after prolonged boiling. A water which neither boiling nor any other method can reduce below 6° of hardness, is to be looked upon as highly objectionable; and one rising above 6° in its natural state is, if possible, to be avoided. If the excessive hardness in any case be due principally to carbonate of lime, there is a method of softening, to which we shall presently advert, so simple and easy, that such a water may be adopted without hesitation, if otherwise eligible.

Particular care must be bestowed on the testing for organic impurity; and the summer and autumn months should be selected for this purpose. The tests above given are quite sufficient to show whether the amount of this species of impurity be so excessive as to disqualify the water for domestic use. If the water be surface water, and has not been exposed for a length of time to natural purification, as in a river of large volume, organic impurity in the hot months is to be almost presumed, and the only question will be one of degree.

The greatest blessing that can happen to a town is to have an abundant supply of soft water from springs. Spring water being always free from organic impurity, having an even and admirably-adjusted temperature throughout the year, and being well aired and of sparkling brightness, it requires only the addition of the quality of softness, and freedom from saline matters generally, to make it absolute perfection for every ordinary purpose of water.

The common case with springs, however, is to show a considerable amount of saline constituents, and those of the hardening kind. In such circumstances there is a choice of difficulties. But, in the first place, the hardness may be removable by the methods already alluded to. In the second place, if the hardness is not removable, a compromise may be made by employing surface or river water of the requisite softness for washing, cooking, &c. and resorting to the springs for drinking water.

In every case of the public supply being from surface drainage or rivers, the springs and wells of the town should be religiously preserved, and made available for the drink of the population. No other water is well adapted for a beverage in the extreme seasons of the year; and it is preferable to every other water at any season. There should be always a sprinkling of wells in a town in addition to the pipe water carried into every house, if that water is not directly obtained from springs: these wells should be maintained at the public expense, and protected from the contamination of drainage, cesspools, and burying-grounds. It should be within the power of every inhabitant of the town to procure at all times a cooling draught fresh from the fountains of mother earth. This precaution was generally overlooked when the new method of extending pipe water to every house was first introduced in towns; but after a few years' experience of river supplies, attention is again directed to the preservation of the wells as the only sources of a pure and exhilarating beverage, unaffected by the vicissitudes of the seasons. It is not possible in the summer months to obtain a water of the proper coolness, and free from vegetation and animalcules, except from springs.

The muddiness of a water is of course an objectionable quality, but it may not be an insuperable objection. If it is perfectly removable by the ordinary sand-filters, it need not stand in the way of a water's being adopted; but there are forms of muddiness that filtration may not clear. The diffusion of fine impalpable clay is almost incurable; and a still greater evil is the slimy matter caused by an excess of organic impurities in the hot months. This kind of solid impurity is extremely difficult to remove by any of the ordinary methods of filtration.

The chalk formations, which yield river waters of about 16° of hardness, contain also springs of the same or still greater hardness, having all the good qualities of spring water, and objectionable only on account of the hardness. The precipitation of the chalk by softening processes leaves those waters in a very high state of purity, and in every way suited for a domestic supply. A softened chalk water is found to be very remarkable for its clearing qualities, and is thus strongly recommended to dyers and calico-printers, as well as for washing purposes generally. When water is derived from the chalk, therefore, the shallow springs are to be preferred to the rivers, being free from organic matter, and often no worse in respect of hardness.

There is a peculiarity attending both the chalk and sandstone waters—namely, their tendency to favour vegetation when kept in shallow ponds. It is found necessary in filtering a chalk water, such as the Thames, to have the water on the filter not less than six feet deep, otherwise plants would take root and choke the filtering bed. But a sufficient depth of reservoir is in all cases a protection against this particular tendency.

The following statement from Professor Clark's evidence exhibits in a strong light the importance of the quality of *softness* in the water chosen for a town supply:—

'The hard water has a tendency to discourage washing of clothes among the poorer classes, and to bring on them great expense in clothes. This consideration bears very closely on the clothing of women and children; and I rather think that if manufacturers of the articles of clothing worn by women and children in a district supplied with hard water—this very London, for example—were consulted, it would appear that they are obliged to supply articles of such dark dyes as will not let the dirtiness be seen. Now to substitute the art of concealing dirt for a habit of cleanliness not only is unfavourable to health and comfort, but is unfriendly to a decent self-respect; yet an observant eye cast on the women and children of the poorer classes in London may discover that such has been the result here.'

In corroboration of this last remark, the following quotation is given from Raumer's England in 1835:—'We returned to the beautiful St James's Park, went through the Green Park to Hyde Park, then into Kensington Gardens, and back to Hyde Park, favoured by the weather, and cheered by the freshness of a spring. . . . . All the women of the lower classes were very simply dressed, *chiefly in black or dark colours*, but few remarkable for beauty.'—Vol. i. p. 212.

FILTRATION OF WATER.

The mechanical impurities of water, or the solid particles rendering it muddy or milky, may in most cases be removed by mechanical means. The two processes for this purpose are *subsidence* and *filtration* :—

The subsidence of solid particles depends on their own weight, as compared with the weight of an equal bulk of water. To favour the process the most perfect stillness should be allowed. It is expedient to have partitions placed in the subsiding reservoirs at short intervals, more effectually to prevent the agitation of the water. The liquor should be run off from the top, and not from the bottom. By making the bottom of the subsiding reservoir form a declivity from opposite sides, and providing means to let off the water occasionally from its lowest depth, it is possible to get quit of the subsided mud.

It is always found of advantage in clearing water from solid particles, whether by subsidence or by filtration, to mix together streams of different qualities. 'Whenever you have any dirty water, the subsidence of the dirty matter is greatly aided by mixture, and a consequent precipitation. The mixture of different waters causes them to act on each other, occasions a readiness to precipitate, and the deposit of floating mechanical matter takes place in this manner much more readily in consequence of the thorough admixture of the two kinds of water. The success of the filtration of water on the large scale I think is greater in Lancashire than in any other part of the United Kingdom. I attribute a very great portion of that success to this arrangement, for it is a point universally known to chemists, that you cannot filter water clearly unless it be in such a state that it will spontaneously deposit the solid matter by subsidence, and leave the water clear.'—(Clark, 'Evidence,' &c.)

There are two methods of filtration—one is known as the Natural Filter, the other is called the Lancashire Filter. The natural filter consists mainly of a bank of sand by the side of a river, through which the water percolates into a tunnel formed underneath to receive it. This filter was first applied at Glasgow, and the Glasgow method was imitated in various other places; but it is now believed to be a failure. The filter bed is often found to yield springs of an objectionable quality of water. A still more fatal objection, and one belonging to the very nature of the construction, is the changing level of the water in the river. It will happen that in hot weather, when water is most in demand, the level is lowest, and the quantity passing through the filter least. The consequence is, that where this filter is employed, it becomes necessary in the summer months to take water from the river direct for the supply of the town.

The Artificial or Lancashire Filter is thus described by Professor Clark: —'Supposing you have a flat horizontal surface to form the bottom of the filter—that is, puddled; above this you spread gravel, and, in general, very large stones. In the spaces between those stones you have the water received, and passing out by means of little tunnels near the bottom. These are formed in a variety of ways. A very good method of forming them has been recently practised, and answers very well—the using simply of agricultural drain-tiles. Those little tunnels are for letting off the filtered water all around them. If you have large stones, the interstices between those stones constitute a receptacle for holding the filtered water. Above the large stones you have large gravel, then smaller gravel, till you come to sand. The whole of the cleansing part of the filter consists of sand. This is of a larger grain than the common sea-sand, except such as we see in rocky districts at the mouths of rivers on the shore—large grained sand of a uniform size. The filter, I think, may be worked so low as four inches of the sand; I think it is constructed at about fourteen inches. From four inches to fourteen inches is a workable depth of sand. The solid matter intercepted does not penetrate perhaps so much as a quarter of an inch, so that by removing a very small film from the surface you get a clear filter; this removal is performed by a workman from time to time. I think that this process of filtration is efficacious in removing mechanical impurities to an extent that could scarcely be believed without seeing the process. What dirty water is thus filtered and used in some of the first manufactories of calico-printers, where one would think good water was at least very desirable, would not have been believed by me to be possible if observation had not made me familiar with the fact. Cleaning the filter is a matter of very small expense in a large manufactory, neither is the structure of the filter expensive. What is scraped off the top is set aside, and at the end of such a period as a year, is washed and put back again on the surface of the filter, so that no renewal of fresh sand is necessary. Such is an outline of the Lancashire filtering.'

In preparing the filter great care is requisite in washing the sand, so as thoroughly to remove all fine particles of clay or mud, and all matters liable to disintegrate and yield impalpable powder in the process of filtering. The washing is performed by exposing the sand to a stream of water sufficient to carry off the lighter matters without sweeping away the siliceous particles. The test of the sand's being thoroughly washed is to put a quantity of it into a tumbler of clear water; and if the sand, after being stirred up, falls down and leaves the water as transparent as before, it may be considered perfectly clean. Should the sand not have attained this degree of purity, or should any milkiness appear in the tumbler, the fine matter remaining will have the effect of rendering the filter inert.

Of all the filters that have been tried, none has yet succeeded so well as the plain sand filter. It is easily cleaned, and requires only the addition of fresh sand at intervals of time. A sand filter has been in operation at the Chelsea Water-Works for twenty years.

The expense of filtering water on the large scale for a town or manufacturing supply is found to be at the rate of one penny for 3000 gallons. A consumption of 100 gallons a day might be filtered for a shilling a year. Considering the great improvement that all surface and river waters undergo by filtration, and the muddiness that such waters are liable to, especially after rains, they ought always to be subjected to the filtering process.

We have already seen that lead is removed from water by filtration. The same will happen to iron if any circumstance leads to the precipitation of the iron into the solid form. Now not only does soluble carbonate of iron tend to become insoluble peroxide, by exposure to air, but the action of organic matter upon iron forms an insoluble compound, which a filter will remove. The entire purification of water containing iron has in actual instances been effected by filtration.

Water highly charged with organic matter may be partially purified by an ordinary filter, inasmuch as part of the impure ingredient may exist in the solid shape as diffused muddy particles. Dissolved organic matter is not removed at the usual rate of filtration; a tainted water will show its taint and breed animalcules after passing through the filter. Whether a slower mode of filtration, more analogous to the natural process that spring water is subjected to, may be introduced into practice on a large scale remains yet to be seen.

CLARK'S PROCESS OF SOFTENING CHALK WATERS.

When the hardness of a water is principally due to chalk or carbonate of lime, which is the case with the waters about London, and over several English counties, nearly the whole of the matter may be thrown down by a simple method discovered and reduced to a workable shape by Professor Clark. The following is an outline of the process given in his own words:—

'To understand the nature of the process, it will be necessary to advert, in a general way, to a few long-known chemical properties of the familiar substance chalk; for chalk at once forms the bulk of the chemical impurity that the process will separate from water, and is the material whence the ingredient for effecting the separation will be obtained. In water, chalk is almost or altogether insoluble, but it may be rendered soluble by either of two processes of an opposite kind. When burned, as in a kiln, chalk loses weight. If dry and pure, only nine ounces will remain out of a pound of sixteen ounces. These nine ounces will be soluble in water, but they will require not less than forty gallons of water for entire solution. Burnt chalk is called quicklime, and water holding quicklime in solution is called limewater. The solution thus named is perfectly clear and colourless. The seven ounces lost by a pound of chalk on being burned consist of carbonic acid gas—that gas which, being dissolved under compression by water, forms what is called soda water.

'The other mode of rendering chalk soluble in water is nearly the reverse. In the former mode, a pound of chalk becomes dissolved in water in consequence of losing seven ounces of carbonic acid. To dissolve in the second mode, not only must the pound of chalk not lose the seven ounces of carbonic acid that it contains, but it must combine with seven additional ounces of that acid. In such a state of combination chalk exists in the waters of London, dissolved, invisible, and colourless, like salt in water. A pound of chalk, dissolved in 560 gallons of water by seven ounces of carbonic acid, would form a solution not sensibly different, in ordinary use, from the filtered water of the Thames, in the average state of that river. Chalk, which chemists call carbonate of lime, becomes what they call bicarbonate of lime when it is dissolved in water by carbonic acid.

'Any limewater may be mixed with another, and any solution of bicarbonate of lime with another, without any change being produced. The clearness of the mixed solutions would be undisturbed. Not so, however, if limewater be mixed with a solution of bicarbonate of lime. Very soon a haziness appears, this deepens into a whiteness, and the mixture soon acquires the appearance of a well-mixed whitewash. When the white matter ceases to be produced, it subsides, and in process of time leaves the water above perfectly clear. The subsided matter is nothing but chalk.

'What occurs in this operation will be understood if we suppose that one pound of chalk, after being burned to nine ounces of quicklime, is dissolved, so as to form forty gallons of limewater; that another pound is dissolved by seven ounces of extra carbonic acid, so as to form 560 gallons of a solution of bicarbonate of lime; and that the two solutions are mixed, making up together 600 gallons. The nine ounces of quicklime, from the one pound of chalk, unite with the seven extra ounces of carbonic acid that hold the other pound of chalk in solution. These nine ounces of quicklime and seven ounces of carbonic acid form sixteen ounces—that is, one pound of chalk, which, being insoluble in water, becomes visible at the same time that the other pound of chalk, being deprived of the extra seven ounces of carbonic acid that kept it in solution, reappears. Both pounds of chalk will be found at the bottom after subsidence. The 600 gallons of water will remain above, clear and colourless, without holding in solution any sensible quantity either of quicklime or of bicarbonate of lime. The weight of chalk separated from the whole waters of the several companies (of the metropolis), estimated at 40,000,000 of imperial gallons, would be about twenty-four tons a day, or 9000 tons a year.'*

This process has been repeatedly exhibited by the inventor on a small scale, and it is now in regular operation on the large scale at Messrs Hoyle and Sons' Printworks, Mayfield, Manchester. Some trials of the process have recently been made at the Chelsea Water-Works. We have been shown a written note of the principal results of the experiments, drawn up by the engineer that conducted them—Mr James Simpson, junior. He says, 'the process seems to work better, and the deposit to take place more quickly, on the large scale than in the laboratory; and the larger the scale, the more prompt the deposit. The deposit appears to consist, not of a precipitate in powder, but of well-defined minute crystals of kalkspar, which enlarge and fall better, in proportion, as the mixture receives more agitation.'

When tried upon specimens of water derived from chalk springs near Watford, it was found capable of reducing the hardness from 17° to 3°. The time required for the precipitation of the chalk and the clearing of the water is less than twelve hours in a water such as is found in the neighbourhood of London. If there be any mechanical or organic impurities in addition to the chalk, or any colouring matter, these are involved in the precipitate, and carried down along with it. In the case of the Thames water much more is removed than the mere chalk. Organic compounds are withdrawn from solution, insects and animalcules are destroyed, and mud carried to the bottom.

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* A New Process for Purifying the Waters supplied to the Metropolis by the Existing Water-Companies. 4th edition. London: Published by R. and J. E. Taylor, Red Lion Street, Fleet Street. 1849.

The Messrs Hoyle adopted the process solely for the sake of its collateral effect in freeing the water from organic matter; and it has been perfectly successful—the success in this respect of course implying success in its main object, for it is only through the precipitation of the chalk that the organic matter is carried down. They state regarding the process—'We operate upon several hundreds of thousands of gallons daily, and we have observed nothing in our operations to lead us to doubt that the process would work well on the largest scale.'

The process, which is essentially an inexpensive one, has been recommended by the General Board of Health to various towns coming under their inspection, in accordance with the provisions of the Public Health Act, and two of the new schemes brought before parliament last session for the supply of water to the metropolis involved its application. With such a process to fall back upon, the inhabitants of London have no need to want a soft and pure water supply.

STORAGE AND DISTRIBUTION OF WATER.

In the intermediate stages between the source of a water and the houses of its consumers, much may be done in the way of either preserving or impairing its purity. The whole of the arrangements for transmitting and distributing the supply are purely of an engineering character; but the works of the engineer have to be controlled by considerations as to the properties of water.

The extent of the storage in reservoirs depends on the nature of the supply. If water is derived from perennial springs, whose minimum flow equals the maximum demand, the storage may be the least possible. If a river is the source, the reservoirs should be large enough to hold such a stock as will carry the consumers over the periods when the river is polluted by rains; they should also be large, on the principle of allowing time for purification by subsidence, especially if artificial filtration be not employed. In places where the supply is obtained from surface drainage, the practice has been to build reservoirs capable of containing a five or six months' supply, it being necessary to provide against the greatest droughts that ever happen in any season.

The reservoirs should be deep, so as to prevent vegetation, and the lining should be of some material that vegetation will not take root in. It is also desirable to shelter them from the action of the sun, which would otherwise raise the temperature and develop animalcules.

In distributing water over a town, two different methods have been adopted, known respectively as the *intermittent* and the *constant* systems of supply. On the intermittent system water is laid on once a day, or once in two days or three days, as the case may be, and fills a tank attached to every separate house, generally low down in the kitchen area, and from this tank the water is drawn off as required. On the constant system no tank is needed, but the house-pipes are kept constantly charged through their unbroken connection with the distributing reservoir. The intermittent supply is employed everywhere in the metropolis; but it is almost universally admitted that the other system is vastly superior in every respect; and in consequence all new works are erected on this system. The disadvantages of the intermittent practice have been strongly set forth in all the recent official reports on sanitary improvement: the expense of the erection and repair of cisterns, the trouble requisite to keep them clean, the contamination of the water by the neighbourhood of sources of pollution, the frequent waste of water that occurs, the difficulties imposed on the poorer class of tenements where cisterns are not provided—are a few of the objections urged against this mode of supply. Dr Hassall's examination of the cistern water of London revealed a frightful amount of pollution—the consequence of placing water already impure in circumstances where the impurity is still further aggravated.

The system of intermittent supply is usually accompanied with the practice of extra charges for high service—that is, if a water is carried to a cistern at the top of a house, instead of being led to the tank in the area, an addition is made to the water rent. For example, the Grand Junction Water-Works Company in London charge 76 per cent. extra for carrying water to the third floor, 59 per cent. to the second floor, 43 per cent. to the first floor, and 26 per cent. to the entrance floor. These charges necessarily operate as a discouragement to the laying on of water to supply baths and water-closets anywhere above the level of the sunk floor. The employment of wooden pipes, which could not bear a high pressure, was the original cause of the low service, and it has been continued after the introduction of metallic pipes. The companies gain exceedingly little by the mode of separate charging for the high service, while the public are deprived of very great conveniences. The method of making a separate charge for baths and water-closets is likewise found to be of little profit to the companies, and of great mischief to the consumers: it only tends to retard the general introduction of these indispensable articles of health and comfort.

It is scarcely necessary to advert to the advantages of laying on water on every individual tenement, over the method of common stand-pipes, where time and labour are wasted for no good. The cost of house-service is so trifling that there is no object gained in obliging the inhabitants to go to the street for their supply. Moreover, the system of stand-pipes is found to be attended with very great waste of water.

As an example of the cost of a public water supply, we may quote the case of Aberdeen, where the works have not been rendered by any circumstance unusually expensive. The supply is administered by the commissioners of police, and is paid for by a public rate. The houses that have no private service contribute 6d. a pound rental, while for private service 9d. a pound is charged extra, being 1s. 3d. on the whole. A house rented at £5, and rated at £4, would pay 2s. a year for access to the public stand-pipes, and 5s. a year for private service. The water-rate at an average of the population is 1s. 2d. a-head, and the amount supplied 12 gallons a-head. Compare this with the water-rate of the metropolis, which is at an average £1, 10s. per house, and upwards of 4s. a-head. It would, however, hardly be possible to supply London at the same rate as Aberdeen—considering the inferior natural position, the magnitude, and the complicated arrangements of the former—but the difference here given is enormous and uncalled for.

ADMINISTRATION OF THE WATER SUPPLY.

In some towns the public water supply has been lodged in the hands of private companies, and in others it has been committed to the public authorities charged with other works relating to the public health—as, for example, drainage, and surface paving and cleansing. Experience has shown that this last method, if instituted from the first, is the best for the public. Private companies, requiring to reimburse themselves for their outlay, must lay an extra charge upon the consumers as profit; but what is of still more consequence, they can only supply on the voluntary principle: hence the poorest class are apt to be neglected if their landlords grudge the cost of the service. Corporations, on the other hand, make no profits, and are armed with powers to carry their supply everywhere, and to exact payment by compulsion.

But the partition of the different public works relating to the health of a town among different authorities is found to be a great obstruction to their effective management. In the metropolis it happens at present that no less than four jurisdictions come to be exercised on the same spot—on a line of street, for example. One body has the charge of the street's crust—the forming and cleansing of the pavement; another has charge of the sewers; a third has the power of entry to lay water-pipes; and a fourth comes and breaks open the street to supply gas. Interference and obstruction are the inevitable result; and the want of a common understanding in laying open the streets is particularly injurious to the character of the pavement, and the convenience of the traffic.

The General Board of Health have laid much stress on the combination of works of drainage with the water supply—the one being, as it were, the continuation of the other. They represent, that had the two been under the same management in the metropolis, in addition to other advantages the water would have been less wasted than it is found to be.

In many of the cases where the management of the water supply has fallen into private hands, and thus become detached from the related works, embracing the interests of the public health, complaints have arisen, and a desire manifested to transfer the management to a public body. But the rights of a company established under an act of parliament cannot easily be set aside, and must in general be purchased at a price beyond their actual present value to the town. Admitting, therefore, the expediency of putting the water supply into the hands of the public authorities in all cases where it is instituted *de novo*, the existence of a company with a large expended capital alters the circumstances considerably. Should the inhabitants of any town resolve to obtain better terms from an existing company than they may have at present, three courses are open to them:—

1. Purchase of the works and interest of the company. This will invariably be a sacrifice to the town to some extent; and the expenditure may be so great as to render it impossible both to improve and cheapen the supply. At Manchester the supply has been transferred to the corporation by purchase; and from the amount paid to the old proprietors, the water-rate must be burthened for ever with a charge for works that no longer

serve the public. The expediency of this method must depend entirely on the nature of the bargain that can be made with the companies. To give them what they would consider a fair price for their plant would sometimes be grossly unfair to the public, and not the most economical way of obtaining the end sought.

2. Another method is to set up a new company under conditions and restrictions such as to give to the public security for good water at a reasonable price. If the kind of water to be supplied were agreed upon, and a maximum rate fixed, the new company would enter the field, and compel the existing company to come to the same terms. This would be to have recourse to competition under a guarantee against the practice, so universal with rival companies, of coming to an understanding, and raising the prices higher than ever. Without some such guarantee the public may lose, but they never can gain, by competition. The 'multiplication of capitals on the same field of supply' causes a loss somewhere, and either the capitalists or the public must bear it. The principle of establishing a new competing company, with restrictions and conditions for protecting the public, has been lately applied in the introduction of a gas supply into the city of London. There will be cases where this plan is a much less evil than buying up existing works at a price far beyond their value.

3. The remaining method is that contained in the provisions of the Public Health, and is carried into operation in all towns where that act is applied. The Local Board of Health in each place is empowered to supply the inhabitants with water, and to carry it into every house, under restriction as to charge; and in providing this supply they are, in the first place, to endeavour to contract with an existing company, if there be a company; but if the company refuse to grant a supply on reasonable terms, the Board may erect works, and obtain a supply independent of the company. In case of a dispute as to terms, the General Board of Health are to be referee in the first instance; and should their award be refused, arbitration is resorted to in a manner provided for in the act. The power thus conferred on the Local Boards of Health is in general found sufficient to secure reasonable terms from existing companies; and the expensive process of purchasing the old works is avoided, while the distribution of the water is put under public control, and every house is secured in a supply. This device may be employed wherever the Public Health Act is introduced; and it may be taken as representing what the wisdom of parliament deems best to be done under the circumstances.

WATER SUPPLY OF THE METROPOLIS.

The supply of water to the vast population of the metropolis has been a subject of anxiety for many years, and is especially so at the present moment. The actual supply is in the hands of nine private companies, who derive it either from the Thames or from streams of the chalk formation. The Thames water has a hardness varying from 11 to 13 degrees on Clark's scale, and is always charged more or less with organic impurity. The system of keeping it in tanks tends to further deterioration; and if to these causes we add the neglect of filtration by most of the companies, it may be readily supposed that the inhabitants in some parts have to use a very objectionable water.

The General Board of Health having been directed by government to investigate the whole question, made their Report to parliament in May 1850. The Board adverted fully to the defects of the existing supply, and without entering into the merits of the schemes propounded by other parties for obtaining an improved supply, they broached the idea of deriving a quantity of water sufficient for the entire metropolis, and unobjectionable in quality, from a tract of barren sandy land in the county of Surrey, part of which is known as the Bagshot Sands. But before alluding more particularly to this plan, we will state briefly the nature of the other schemes at present before the public for the same purpose.

1. One method is to derive a supply from the Thames at a higher point than the source of any of the existing supplies. One party has fixed upon Henley as the proper point, and another would take it still higher—at Maple Durham. The distance of Maple Durham from London is nearly forty miles; and the water obtained there would escape the contamination, not of the London sewage merely, but also of the sewage of the other populous towns higher up on its banks. The promoters of the Maple-Durham scheme propose to soften the water by Clark's method; the promoters of the Henley scheme—who brought a bill into parliament last session, which was thrown out in consequence of the opposition of the government—did not undertake to soften the water; but there can be no doubt that any fresh supply from the chalk would be unsatisfactory if it were not first softened by this very cheap and effectual process. It is pretty certain that water taken so near the sources of the Thames, and deprived of three-fourths of its chalk, would be, as far as quality is concerned, an eligible supply.

2. The second method consists in resorting to chalk springs, or to the sources of the river waters about the metropolis, where a supply of water entirely free of organic impurity may be obtained, and having no objectionable point except the hardness. But the hardness of pure chalk waters can be almost wholly removed by the softening process, and the spring water thus treated becomes of the highest degree of purity. A company has been formed to provide a supply on this principle from springs at Bushey Meadows, near Watford, for the benefit of the north-western division of London. The lime process reduces the hardness of this water from 17 to 3¼ degrees of hardness, which, in fact, may be accounted a perfectly soft water; and there being no organic impurity, the water would be in all respects of first-rate quality. The even temperature of springs would belong to it: and while probably containing no excess of carbonic acid to act on the pipes, it would be found to have the amount of dissolved atmospheric air usual in spring water. The Watford springs would supply only a fraction of the metropolis: but similar springs exist in many other parts of the London basin. The principle of the supply is, to mount to the springs that feed the rivers, instead of taking the rivers themselves.

3. Captain Vetch, an engineer in the service of the government, and one of the metropolitan Commissioners of Sewers, has, in his evidence before the General Board of Health, given as the results of a survey of the rivers about the metropolis the following as eligible sources of supply:—First, the river

Lea near Hertford, from which an aqueduct 14 miles long might bring in a supply of 7,000,000 of cubic feet per day, and deliver it at an elevation of 140 feet above Trinity high-water mark; second, the river Darenth, south of the Thames, and below London, to be conveyed in an aqueduct 13 miles long, and to bring in a supply of 3,000,000 of cubic feet per day; third, the river Colne, to be conveyed in an aqueduct 12 miles long, and to bring in 3,000,000 of cubic feet; fourth, the river Mole, to be connected with the metropolis by an aqueduct 15 miles long, to bring in from a point on the course of that river, a little way above the village of Betchworth, about 3,000,000 of cubic feet per day. Captain Vetch's supply would thus amount to 16,000,000 of cubic feet, or 100,000,000 gallons a day; nearly double the present supply, and more than double the amount that the General Board of Health consider requisite for all the purposes of the metropolis. Two of the smallest of these sources would afford the quantity needed according to the Board's estimate of the supply. The quality would be pure chalk water, requiring only the application of the softening process.

4. The scheme of the General Board of Health consists, as has been stated, in obtaining a supply from the Bagshot Sands. The water derived from these sands had previously been known to be remarkably soft, specimens of it varying from 3 to 6 degrees of hardness. The Board, at the date of the publication of their Report, were not aware that spring water could be obtained from those sands in sufficient amount for the supply of the metropolis, and proceeded on the supposition, that the surface water of the sands and heath would require to be used along with whatever might be obtainable from springs of the degree of softness desired. But the examinations made subsequently have gone to show, that the area in question is capable of furnishing an adequate supply from springs alone, and therefore that the surface water, which is to a great extent contaminated with peat, may be dispensed with. In consequence of a Report made to the Board by the Hon. William Napier, who examined the ground at their request, which Report set forth the abundance of spring water of not more than two degrees of hardness, and the greater part of it of less than one degree, the Board directed Mr Rammell, one of their engineering inspectors, to make a fresh gauging of the springs; and from his Report we extract the following particulars relative to the proposed supply:—

'The total area included is of very considerable extent. Taking Farnham as a point of departure, the district stretches northward beyond Sandhurst and Bagshot to Wokingham, Sunning Hill, and Virginia Water, and southward to the distant villages of Bramshot and Haslemere. On the western side its limits would be defined by a nearly straight line passing through Barkham, Eversley, Crondall, and Kingsley; while its eastern and south-eastern boundary, which is extremely irregular, would be marked by Chobham, Pirbright, Guildford, and Dorking, and the high water-shed line stretching from the Leith Hill to the Hind Head. The length from north to south is about 25 miles, and the extreme breadth from east to west about 24 miles; the whole area included exceeding 300 square miles.

'Parts of four distinct drainage areas are included within the limits. The valley of the Wey runs along the eastern side of the northern section, and across nearly the whole of the southern section. The Blackwater, and other tributaries of the Loddon, drain the large remainder of the northern section, except the upper part of its eastern side, which draws into the Bourne Brook. The extreme western end of the southern section falls towards the mole.'

Mr Rammell gauged the flow of twenty-one spring-water streams falling into the Wey, nineteen streams falling into the Loddon, six into the Bourne Brook, and one into the Mole, and found the united body of water equal to 51,375,000 gallons. The gaugings were taken in the latter end of October, about the termination of the dry season; and it may be presumed that at least an equal flow may be obtained all the year round. To this was to be added another district supposed capable of yielding 10,000,000 gallons additional.

'It follows, then,' says Mr Rammell, 'as the result of my examination and gaugings, that the minimum available yield of the deep springs of the district may be estimated in round numbers at 61,000,000 gallons daily, of which quantity 51,000,000 have been ascertained by Mr Napier not to exceed 1 degree of hardness, and the remaining 10,000,000 is considered by him to be under 2 degrees of hardness.'

The only objectionable qualities known to inhere in Bagshot spring water are, the presence of iron and an excess of carbonic acid. The carbonic acid would act in corroding the lead and iron pipes. It still requires to be ascertained what is the extreme amount of these injurious ingredients, and how far precautions may be taken against them. The promise of spring water of such remarkable softness naturally holds out great attractions to the inhabitants of the metropolis.

After the search for sources of supply has been completed, and a rigorous comparative examination made into the qualities of all the different waters, there will remain the consideration of engineering cost, and on it will depend the final decision of the question.

The future administration of the Metropolitan Water Supply presents far greater difficulties than the choice of the water. The General Board of Health recommend that it should be intrusted to a small paid commission appointed by the crown, and having also the management of the sewage. The absence of any municipal body for the metropolis at large makes its local administration a peculiar case; and the sewage is already in the hands of a Government Board.